

Manufacturing Completion of the First ITER VV Sector

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ABSTRACT

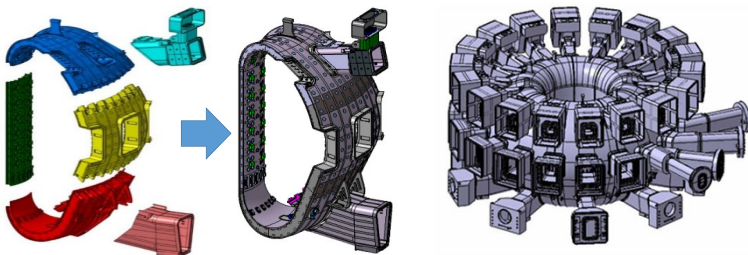
• In 2020, manufacturing of the 1st sector of the ITER Vacuum Vessel has been completed since manufacturing start in Feb 2012. Each step of the manufacturing was challenge as a First-of-a-Kind (FOAK) and a French Nuclear Pressure Vessel. The paper provides an overview of the major technical challenges which were overcome during the 1st ITER VV sector manufacturing and lessons learned over the last 10 years.

CHALLENGES

ITER Vacuum Vessel (VV) sector and Requirements

ITER VV – Sector as delivery

Whole assembled VV at ITER site



Major requirements

Safety	PIC (Protection Important Class) components according to French order dated 7 Feb 2012 (INB Order)
Nuclear Pressure Vessel	Level N2 & Cat. IV NPE according to the guidelines of the ASN for application of French Order dated 30 Dec 2015 (ESPN Order) Agreed Notified Body (ANB) for conformity assessment
Code	RCC-MR 2007 edition
Tolerance	Accurate field joint fit-up and precise assembly of in-vessel components
Welding	Full penetration welding

MANUFACTURING CHALLENGES AND OVERCOMING

• Nuclear Safety Process

- ✓ Required a great deal of time & effort to proceed manufacturing by a long documents review & approval process, and the complicated work interface → **A necessity arose for process simplification!!**
- ✓ **VV Project Team (VVPT) created in 2015** for simplified & effective project management as one team spirit (IO-CT + IO-DAs)
- ✓ Whole process greatly simplified after implementation of the VVPT

• Tight manufacturing tolerances

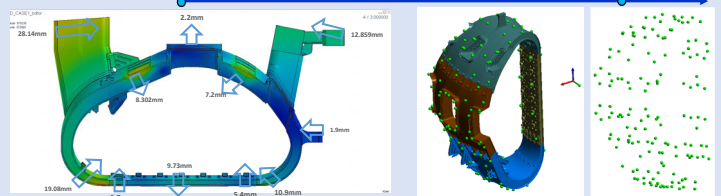
- ✓ **Narrow gap gas tungsten arc welding** as a basic welding process (+electron beam welding) to minimize welding distortion
- ✓ Developed fabrication sequence based on the results of welding distortion analysis and full scale mock-ups manufacturing
- ✓ **Dedicated jigs** from each segment manufacturing stage to minimize welding deformation
- ✓ **Virtual fitting in advance** using 1) as-built dimensional inspection data of each segment, 2) required weld root matching tolerance for gap & misalignment, 3) welding distortion analysis results for the final assembly according to HHI's welding sequence

• 100% inspection requirement by ESPN order

- ✓ **15 times of Phased Array UT qualifications completed** (with 157 qualification blocks and 141 documents) **under VVPT & ANB witness**
- ✓ To achieve 100% volumetric examination requirement, **all special cases technically verified and qualified successfully**
- ✓ **100% visual inspection on backside welds by ESPN Order is another technical challenge because direct visual inspection is not possible**
- ✓ **Dedicated guiding tool system developed based on precise endoscope system and successfully qualified**

Final assembly based on virtual Fitting

Virtual Fitting based on final 3D result of each PS and PSE for reference position set-up for each Fiducial Posts based on 1) tolerance, 2) as built dimension, 3) required weld fit-up tolerance, 4) welding distortion analysis results



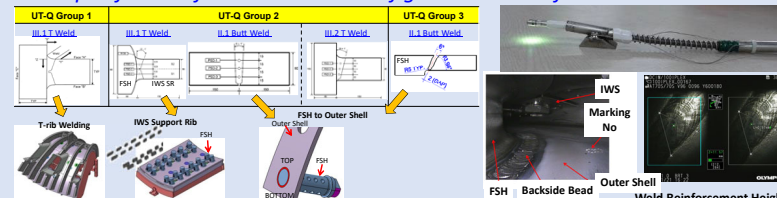
PS1 and PS3 Fit-up

PS2 and PS4 Fit-up and Welding/NDE

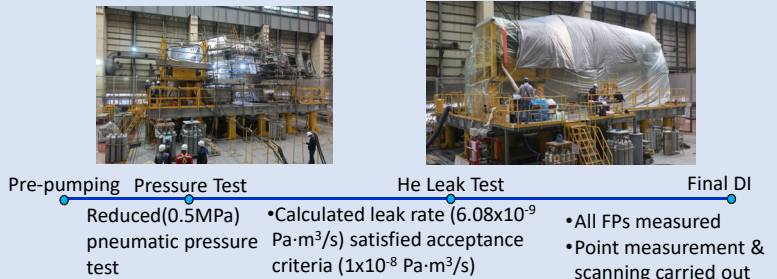
UPSE & LPSE Assembly and Jig removal



PAUT qualification for various weld configurations RVE for weldment backside



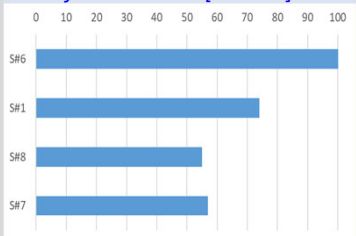
Factory Acceptance Test



LESSONS LEARNED

- Expected significant manufacturing schedule reduction for the remaining KO sectors by 1) improved document management system and the updated quality control to prevent similar non-conformities, 2) several technical improvements.

Expected manufacturing duration for KO sectors [months]



- It's clearly recognized that the importance of the regulation and code for manufacturing of the ITER VV sector. The appropriate regulation and code need to be developed for VV of a future fusion power plant which well balanced between economic and safety point of view.

ACKNOWLEDGEMENTS / DISCLAIMER

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- The views and opinions expressed herein do not necessarily reflect those of the ITER Organization